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AQUATIC MONITORING OF THE 1976 SPRUCE BUDWORM CONTROL PROJECT IN WASHINGTON STATE

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
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A REPORT ON:
AQUATIC MONITORING
OF THE 1976 SPRUCE BUDWORM
CONTROL PROJECT
IN WASHINGTON STATE

by

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SUMMARY

1. During the summer of 1976 approximately 350,000 acres of Federal, State, and private lands in Washington State were treated with the organophosphate, Malathion, and 7,600 acres were treated with the carbamate Sevin-4-Oil to control a spruce budworm infestation on the eastern slopes of the Cascade Mountains.
2. The project was administered by the U. S. Forest Service headquartered at Cashmere, Washington with subunit headquarters at Twisp, Wenatchee and Ellensburg, Washington.
3. The Washington State Department of Ecology was contracted to monitor for pesticide residues in the aquatic environment and to conduct impact studies on the effects of the aerial spray project on aquatic organisms.
4. The techniques and equipment employed were similar to those used during the 1975 monitoring study^{2/}.
5. A statistical test was conducted on the water sampling data which tests the hypothesis that the means of the pesticide concentrations in the sampling runs are equal to the mean of the pesticide concentrations in the control^{3/} (Table 7).
6. A second statistical test was conducted which tests the hypothesis that the means of the pesticide concentration in water samples collected from the buffered streams are equal to the means of the

pesticide concentrations in water samples collected from non-buffered streams. This test raised questions regarding the practicality of buffering streams during aerial pesticide applications involving forested lands in mountainous regions.

7. Impacts of the aerial spray project appeared to be relatively greater on small streams than on large; damage, if any, was minimal and confined to the spray block and a 2-mile reach of the stream below the spray block.
8. It is recommended that a dedicated effort be directed toward determining whether or not buffering during aerial pesticide applications in mountainous forested lands is practical. If so, it is further recommended that necessary steps be taken to increase buffering efficiency.
9. The following tabulation summarizes the results of the monitoring project:

SUMMARY OF AQUATIC MONITORING RESULTS

STREAM NAME/ DESCRIPTION	PESTICIDE RESIDUE SAMPLING	BIOLOGICAL IMPACT SAMPLING	COMMENTS
<u>MALATHION</u>			
<u>HANSEL CREEK (NON-BUFFERED)</u> Small (12 cfs) creek located in T23N, R17E near Blewett Pass, Chelan County. Sprayed about 1.5 square miles near headwaters.	Stream water residues increased from 0 to 37 ug/l shortly after spraying, then dropped to prespray levels. No Malathion was detected in any of the 48-hour postspray residue samples (water, fish, insects, etc.).	Drift insect counts increased from 5 to 1,003 insects/100 cff shortly after spraying, then declined to prespray levels. No insect or fish livebox mortalities. Altered diversity and decreased abundance of benthic insects.	Project caused a moderate increase in activity on aquatic insect communities inhabiting the stream. Fish not affected.
<u>GOLD CREEK (NON-BUFFERED)</u> Small (4 cfs) creek located in T32N, R21E, near Twisp, Okanogan County. Sprayed 4 stream miles, both sides	Stream water residues increased from 0 to 42 ug/l shortly after spraying, then dropped to prespray levels. No Malathion was detected in any of the 48-hour post spray residue samples (water, fish, insects, etc.).	Drift insect counts did not increase after spraying. No insect or fish livebox mortalities. Altered diversity and reduced abundance of benthic insects.	Minimal increase in insect activity. Stream protected fairly well by forest canopy except for clearing where samples collected.
<u>NASON CREEK (BUFFERED)</u> Large (900 cfs) stream located in T26N, R15 and 16E, near Stevens Pass, Chelan County. Sprayed 5 stream miles both sides.	Stream water residues increased from 0 to 3 ug/l shortly after spraying, then dropped to prespray levels. No Malathion was detected in any of the 48-hour postspray residue samples (water, fish, insects, etc.).	Drift insect counts did not increase after spraying. No insect or fish livebox mortalities. No apparent alterations in diversity or abundance of benthic insect populations.	Did not detect any adverse impacts on aquatic life.
<u>LITTLE BRIDGE CREEK (BUFFERED)</u> Medium (20 cfs) stream located in T34N, R20E near Twisp, Okanogan County. Sprayed along 2 stream miles one side.	No Malathion detected in stream water during sprayday. The 48-hour postspray water sample contained 10 ug/l Malathion (possible contamination) but not detected in fish, insects, etc.	Drift counts did not increase after spraying. No insect or fish livebox mortalities. No apparent alterations in diversity or abundance of benthic insect populations.	Did not detect any adverse impacts on aquatic life. Could have sprayed near stream during day of postspray sampling.

SUMMARY OF AQUATIC MONITORING RESULTS

(Continued)

STREAM NAME/
DESCRIPTION

PESTICIDE RESIDUE SAMPLING

BIOLOGICAL IMPACT SAMPLING

COMMENTS

MALATHION

TANEUM CREEK (BUFFERED)

Medium (114 cfs)
stream located in T19N,
R15E, near Ellensburg,
Kittitas County. Spray
day 1 - sprayed along 2
stream miles one side.
Sprayday 2 - sprayed
along 2 stream miles one
side. Sprayday 3 -
sprayed along 8 stream
miles both sides.

Sprayday 1 - Stream water residues
increased from 0 to 17 ug/l shortly
after spraying, then dropped to pre-
spray levels. No Malathion detected
in 48-hour postspray samples (water,
fish, insects, etc.).

Sprayday 2 - Stream water residue
samples not taken. No Malathion
detected in 48-hour postspray samples
(water, fish, insects, etc.).

Sprayday 3 - Stream water residues
increased from 0 to 4 ug/l shortly after
spraying, then dropped to prespray
levels. No Malathion was detected in
postspray samples (water, fish,
insects, etc.).

Sprayday 1 - Drift insect counts in-
creased from 2 to 41 insects/100 cff
after spraying, then dropped to pre-
spray levels. No insect or fish livebox
mortalities. Altered diversity and
reduced abundance of benthic insects.

Sprayday 2 - Drift insect counts in-
creased from 3 to 11 insects/100 cff
after spraying then dropped to prespray
levels. No insect or fish livebox
mortalities. No apparent alterations
in diversity or abundance of benthic
insect populations.

Sprayday 3 - Drift insect counts in-
creased from 5 to 863 insects/100 cff
after spraying, then dropped to prespray
levels. No insect or fish livebox
mortalities. Altered diversity and
reduced abundance of benthic insects.

Minimal increase in insect activity.
Fish not affected.

Minimal increase in insect activity
Fish not affected.

Moderate increase in activity among
insect communities. Fish
not affected.

TEANAWAY RIVER MF
(BUFFERED)

Medium (180 cfs)
stream located in T22N,
R16E, near Cle Elum,
Kittitas County. Spray-
day 1 - Sprayed about
1/2 mile of stream both
sides; Sprayday 2 -
Sprayed 5 stream miles
both sides.

Sprayday 1 - Stream water residue
reached about 1 ug/l shortly after
spraying, then dropped to prespray
levels. No Malathion detected in
48-hour postspray samples (water,
fish, insects, etc.).

Sprayday 2 - Stream water residue
reached 21 ug/l shortly after spraying
then dropped to prespray levels. No
Malathion detected in 48-hour postspray
samples (water, fish, insects, etc.).

Sprayday 1 - Drift insect counts did not
increase after spraying. No insect
or fish livebox mortalities. No
apparent alterations in diversity or
abundance of benthic insect populations.

Sprayday 2 - Drift counts increased from
about 10 to 620 insects/100 cff after
spraying, then dropped to prespray levels.
No apparent alterations in diversity or
abundance of benthic insect populations.

No increase in insect activity.

Moderate increase in insect activity.
Fish not affected.

SUMMARY OF AQUATIC MONITORING RESULTS

STREAM NAME/
DESCRIPTION

PESTICIDE RESIDUE SAMPLING (Continued)

BIOLOGICAL IMPACT SAMPLING

COMMENTS

SEVIN-4-OIL

GATE CREEK (NON-BUFFERED)

Small (5 cfs) stream located in T36N, R19E, near Mazama, Okanogan County.

Stream water residue increased from 0 to 11 ug/l shortly after spraying, dropped to prespray levels. No Sevin-4-Oil detected in 48-hour postspray residue samples (water, fish, insects, etc.).

Drift insect counts increased from 5 to 2488 insects/100 cff shortly after spraying, then dropped to prespray levels. No insect livebox mortalities. Significant fish livebox kill. Altered diversity and reduced abundance of benthic insects.

Pronounced increase in activity of aquatic insect communities. 20% loss of live box fish. Stream protected by forest canopy.

YELLOW JACKET CREEK (NON-BUFFERED)

Small (.4 cfs) creek located in T36N, R19E, near Mazama, Okanogan County.

Stream water residue increased from 0 to 5 ug/l shortly after spraying, then dropped to prespray levels. No Sevin-4-Oil detected in 48-hour post-spray residue samples (water, fish, insects, etc.).

Drift insect counts increased from 2 to 51 insects/100 cff shortly after spraying, then dropped to prespray levels. No insect or fish livebox mortalities. Altered diversity and reduced abundance of benthic insects.

Moderate increase in activity among aquatic insect communities. Fish not affected. Stream protected fairly well by forest canopy.

Note: cff = cubic feet flow
ug/l = parts per billion

INTRODUCTION

Approximately 350,000 acres of Federal, State and private lands within Washington State were treated with the organophosphate, Malathion during the summer of 1976. An additional 7600 acres was sprayed with the carbamate insecticide, Sevin-4-Oil. This project was initiated by the U.S. Forest Service in an attempt to control a serious outbreak of the western spruce budworm (Choristoneura occidentalis) on the eastern slopes of the Cascade Mountains of Washington State.

BACKGROUND

The spruce budworm is a moth (Lepidoptera) insect in its larvae stage. It feeds on the buds and new needles of conifers causing extensive damage each year. The most severely impacted are Douglas fir, white fir and grand fir.

The current western spruce budworm outbreak occurred in 1970, involving some 18,000 acres of the Wenatchee and Okanogan National Forests. The infestation spread to more than 500,000 acres by 1975. The 1976 infestation estimate is 1.1 million acres and further damage is inevitable.

During the summer of 1975, the USFS conducted efficacy tests at different application rates of the organophosphate Fenitrothion on the spruce budworm. Results of these studies are available from the USFS Director of Insect and Disease Management, Portland, Oregon.^{1/} The impacts of

the Fenitrothion applications on the aquatic environment were monitored by the Department of Ecology under contract with the USFS. The results of the DOE study indicated that the impacts of the project, if any, were minimal.^{2/}

The U. S. Forest Service also contracted the Washington State Department of Ecology to monitor the 1976 pesticide application. The agreement was documented under Contract Number 006065N issued on June 10, 1976. The \$35,500 contract stipulated the DOE analyze for the incidence of Malathion and Sevin-4-Oil in the aquatic environment and assess the impacts, if any, of the pesticides on aquatic organisms.

Aerial Spray Project

The 1976 Spruce Budworm Control Project was administered by the U. S. Forest Service under the supervision of David Graham, Director of Insect and Disease Management, Portland, Oregon. Jack Mounts, Project Director, coordinated the field activities with headquarters at Cashmere, Washington.

The project was divided into three control units for the Malathion application, as follows:

<u>Unit No.</u>	<u>Unit Name</u>	<u>Headquarters</u>
1	Okanogan	Twisp, Wa.
2	Wenatchee	Cashmere, Wa.
3	Ellensburg	Ellensburg, Wa.

The primary control units were divided into the following subordinate units:

<u>Unit No.</u>	<u>Subunits</u>
1 - Okanogan	Twisp, Winthrop, Mazama, Early Winters
2 - Wenatchee	Icicle, Nason, Chiwawa
3 - Ellensburg	Teanaway, Taneum, Swauk, Warm Springs

In addition, a 7600-acre block on the southwest slope of Goat Peak near Mazama, Washington was treated with the carbamate insecticide Sevin-4-Oil. The Sevin-4-Oil treatment block was managed by the Okanogan Unit staff.

Each control unit was administered by a Unit Supervisor. The Okanogan and Wenatchee Units were staffed with Forest Service personnel while the Ellensburg Unit was staffed with Washington State Department of Natural Resources personnel.

Streams that flow through the spray blocks that received pesticide applications during the 1976 Spruce Budworm Control Project varied in flow rates from about five cfs for the small creeks to over one thousand cfs for the larger rivers. The U. S. Forest Service directed the pesticide application contractors to "buffer" all waterways under the provisions of the Washington State Forest Practices Act. "Buffered" streams were provided a 100-foot wide nonspray strip along each bank. Buffered and nonbuffered streams that were monitored for impacts and sampled for residues are shown in the Appendix (Table 1).

METHODS

Sampling procedures employed during the aquatic monitoring study of the 1976 Spruce Budworm Control Project were basically the same as those used during the 1975 Fenitrothion project^{2/}. The two major phases of the current monitoring study were; (1) to collect samples for analysis of pesticide residues, and (2) to conduct studies to determine the effects of the aerial spray project on the aquatic environment.

Four procedural changes were incorporated into the impact study phase of the monitoring program during 1976 as compared to the 1975 project:

1. Where possible, more sampling stations were established on the index streams covering more stream distance in an effort to determine the downstream boundary of the impact zone.
2. Drift insect sampling was conducted only at Station 1 while more emphasis was placed on insect live box studies.
3. A method of sampling stones from the stream bottom was developed for quantifying benthic insects for before and after sprayday comparisons.
4. A statistical analysis was conducted on the pesticide residue data.

AQUATIC MONITORING PREPARATIONS

Personnel

The three permanent employees of the DOE Biological and Chemical Investigations Sections were supplemented by four temporary employees and two summer interns to conduct the monitoring program. Three crews were designated from these nine monitoring team members. One three-person crew conducted the sampling activities in the Ellensburg Unit and two crews worked together sampling in the Okanogan and Wenatchee Units.

Vehicles

Two van-type vehicles were equipped to serve as mobile laboratories. Three additional agency vehicles; a pickup truck, a station wagon and a compact car; were used for general transportation and to transport samples to the Wenatchee Pesticide Laboratory.

MATERIALS AND EQUIPMENT

- * One liter and one-half liter bottles were used to collect and transport residue samples.

- * A Smith-Root Type VII Battery Powered Back Pack Electro Fisher, manufactured by Smith-Root Inc., 14014 N.E. Salmon Creek Avenue, Vancouver, Washington, was used to stun fish for capture.

- * A 363-micron mesh fyke net with a 12" by 18" opening was used for collecting drift insect samples.
- * A galvanized volumetric displacement bucket was used for measuring the displacement volume of the stones that were sampled.
- * Insect live boxes were fabricated from 4-inch PVC pipe perforated with 1/2-inch holes and lined with plastic window screen. The top and bottom openings were covered with Tupperware friction-type lids.
- * Fish live boxes were fabricated from 12" by 18" fiberglass pipe; the ends were covered with nylon netting held in place by rubber straps.

SAMPLING LOCATIONS

Biological impact and chemical residue sampling was conducted on two index streams in each of the three major Malathion spray units and in the Sevin-4-Oil spray block on Goat Peak (Table 1). The eight index streams were selected during the first week in June. Control streams were designated during the prespray sampling run.

If possible, five sampling stations were established on each stream monitored (Figure 1). The first station was located within the spray area boundary; the four remaining stations were established below the boundary at approximately one mile intervals. Due to the extreme gradient of the streams on Goat Peak and the short distance

to the Methow River, only three stations were designated on Yellow Jacket and Gate Creeks. Adequate control stations were established on unaffected streams.

SAMPLING SCHEDULE

The prespray sampling run (Run #1) was conducted within one week prior to spray application. The sprayday sampling period (Run #2) began at 0000 hours and continued for 12 to 14 hours thereafter. On most index streams, postspray sampling run (Run #3) was completed within 48 hours after sprayday.

A schematic showing the sampling station layout and the samples collected at each index stream and nonspray sampling station is shown in Figure 1. Samples to be collected at each sampling station for all phases of the monitoring schedule are shown in Table 2.

FIELD SAMPLING PROCEDURES

Field sampling procedures address four aspects of environmental sampling: residue and biological sampling, stream surveys and water quality chemistry. Most of the water quality, biological and residue samples were collected at Stations 1 and 5, however, in some cases five stations could not be established or sampling was impractical. In such cases, alternatives were employed as necessary in designating the downstream sampling station.

Residue Sampling

Water, fish and benthic organisms were collected for Malathion and Sevin-4-Oil residue analysis as required (Figure 1) (Table 2).

Water. Water samples were collected at Station 1 on index streams at half-hour intervals from midnight until noon the following day for thirteen hourly composites. Water samples were packed in ice as they were collected and transported to the Wenatchee Pesticide Laboratory upon termination of sampling. Prespray and postspray grab samples also were collected from index and control streams as required. In addition, water samples were taken from potable water sources as requested by the USFS.

Fish. Fish samples were collected at Stations 1 and 5 from the project streams with an electro shocker; they were placed in properly labeled bottles, packed in ice and transported to the laboratory. In streams not containing fish, samples were obtained from the live boxes.

Benthic organisms. Benthic organisms were collected at Stations 1 and 5 from the stream bottom by stirring the substrate and allowing the current to carry released aquatic benthos into a fine mesh net. The captured organisms were placed in properly labeled sample bottles, packed in ice and transported to the laboratory for residue analysis.

Biological Impact Sampling

Four independent types of biological samples were collected to assess the impacts of the spray project: drift insect samples, quantitative benthic samples, live box fish and live box insects. In addition, physical and chemical parameters were taken and stream surveys were conducted on program streams.

Drift insect sampling. Drift insects were collected at Station 1 on index streams for a 10-minute period each hour. Captured insects were counted by Order and computed in terms of insects per 100 cubic feet of flow through the drift nets. Water samples were collected concurrently with the drift insect samples permitting a graphical relationship of pesticide concentrations and drift insect counts (Figures 2, 3 and 4).

Quantitative benthic sampling. Quantitative benthic samples were collected at Stations 1 and 5. Twelve stones, about four to five inches in diameter were selected by size and shape. Each stone was cleaned individually with 70% alcohol into a dissecting pan. The volume of the stone was determined by displacement which was converted to the equivalent of a spherical surface area. The insects were counted by Order; high count per stone and low count per stone was discarded. The data was presented in terms of insects per 100 square inches of surface area of the 10 remaining stones.

Insect live boxes. Three insect live boxes were placed at Stations 1 through 5. One box contained 20 Ephemeroptera (mayflies), another 20

Plecoptera (stoneflies) and the third 20 Trichoptera (caddisflies). The insects were allowed to acclimate approximately 12 hours. They were checked about two hours before the pesticide application; dead or weakened insects were either replaced with healthy specimens, or removed. Upon termination of drift insect sampling (about 1400 hours), live box insects were inspected for mortalities and the data was recorded in terms of live and dead insects.

Fish live boxes. Fish live boxes were placed in project streams at Stations 1 and 5 and acclimated about 48 hours prior to spray application. Approximately two hours before sprayday they were checked for mortalities and again 24 to 48 hours after sprayday. Data was recorded in terms of live and dead fish.

Stream Surveys

Stream surveys were conducted immediately prior to the aerial spray application and immediately thereafter. The prespray survey consisted of examining stream conditions in the vicinity of, and above, the sampling stations to insure that no phenomenon was occurring that may alter stream conditions in a manner that would affect the impact study in progress. In addition, the survey included a check of the stream waters and adjacent areas for unusual signs; such as, dead or dying fish, insects, birds, etc. Spray cards were placed along the index stream banks to indicate rate of spray application. The cards were retrieved during postspray surveys.

Water Chemistry

Chemical parameters, including pH, temperature, dissolved oxygen and alkalinity, were measured before and after the aerial application at Stations 1 and 5 on each program stream.

RESULTS

The concentrations of Malathion and Sevin-4-Oil residues extracted from water, fish and biological samples collected during the monitoring study of the 1976 Spruce Budworm Control Project are presented in the appendix of this report. Concentrations of pesticides in water samples are shown in ug per one liter of water or parts per billion (ppb); concentrations of pesticides in insects and fish tissues are presented in terms of ug per gram of tissue or parts per million (ppm). The data is categorized by sample type, stream, station number, sampling run, and date (Tables 3 through 6).

In the interest of brevity, data from three of the eight index streams monitored are shown here to demonstrate the impacts of Malathion and Sevin-4-Oil on selected aquatic macro-organisms. The streams were chosen from three basic categories as follows: (1) Hansel Creek, a stream that was not buffered during the aerial application of Malathion; (2) Middle Fork Teanaway River, a stream that was buffered during the aerial application of Malathion; and (3), Gate Creek a stream that was not buffered during the aerial application of Sevin-4-Oil (Figures 2, 3 and 4).

The results of the monitoring study are presented in two sections:
PESTICIDE RESIDUE and IMPACT STUDIES.

PESTICIDE RESIDUE

A test of significance called the "u-Test" was conducted on the water sampling residue data to compare the means of the sampling runs to the means of the control.^{3/} However, neither the insect nor the fish samples contained detectable levels of Malathion or Sevin-4-Oil concentrations prohibiting a statistical comparison of pesticide residues in tissue.

Test of Significance

The "u-Test" utilizes the standard error of the mean as the denominator in the following equation^{3/}:

$$u = \frac{\mu_1 - \mu_0}{\sqrt{\frac{\sigma^2}{n}}}$$

where;

μ_1 = Mean of sampling Runs #2 and #3

μ_0 = Mean of control

σ = Standard deviation of sampling Runs #2 and #3

n = Population size of Runs #2 and #3

The test is based on the statistic "u" which follows the normal distribution with mean equal to zero and standard deviation to 1. The assumptions are that the sample is random and that the population is normal.

The u -value is a pure number; it does not quantify ppb Malathion, percent, etc. It is a numerical value that is used to test the

hypothesis that the population mean is equal to a given value. In this analysis, the u-value is employed to test the hypothesis that the population means of Runs #2 and #3 are statistically equivalent to the population mean of the control.

The critical regions are where $u < -1.96$ and where $u > 1.96$ at the 5% significance level. If the u -value falls within the 95% portion of the distribution curve which lies between -1.96 and 1.96 , the conclusions are that the means are statistically equivalent. If, however the u-value falls inside one of the critical regions; that is, if $u < -1.96$ or $u > 1.96$ the conclusions are that the means are not statistically equivalent.

u-Test, sampling run means versus control mean. The u-Tests conducted on Malathion and Sevin-4-Oil data were processed separately. Prespray (Run #1) and control water sampling data were pooled to comprise the control. The population size (n), the means (μ) and the standard deviation (σ) for the pesticide concentration summations in the water samples that were collected during Runs #2 and #3 are shown in the following table. In addition, the u-Test results comparing the means of Run #2 and #3 with the mean of the control are presented (Table 7):

Table 7. Statistical comparison of pesticide residues in water samples. Sampling Runs #2 and #3 versus control. Monitoring the 1976 Spruce Budworm Control Project in Washington State. DOE 1976.

Malathion				Sevin-4-Oil			
Statistic	Controls	Run #2	Run #3	Statistic	Controls	Run #2	Run #3
n	50	52	17	N	12	19	3
μ	0.00	4.81	1.14	μ	0.00	2.37	1.03
σ	0.00	9.16	3.10	σ	0.00	3.45	0.00
u-Test	--	3.79	1.52	u-Test	--	2.99	1.98

The Malathion u-values for Runs #2 and #3 are 3.79 and 1.52, respectively. The Run #2 u-value is inside the right critical region indicating that the sprayday sampling run mean does not fall within the same normal curve distribution as that of the control. The Run #3 u-value falls between -1.96 and 1.96 indicating that the Run #3 mean and the control mean are statistically equivalent; that is, both means fall within the same normal curve distribution.

The Sevin-4-Oil Run #2 and #3 u-values are 2.99 and 1.98, respectively. Both u-values are inside the right critical region indicating that neither sampling run mean is statistically equal to the control mean which indicates that the means of Runs #2 and #3 fall within a higher normal curve distribution than that of the control.

u-Test, buffered versus non-buffered streams. The u-Test also was employed on the pesticide residue data set to determine the effects of buffereing utilizing the u-value equation:

$$u = \frac{\mu_1 - \mu_0}{\sqrt{\frac{\sigma^2}{n}}} \quad \text{where;}$$

<u>Test #1</u>	<u>Test #2</u>
μ_1 = Means of Groups A,B,C, & D	μ_1 = Means of Groups B,C & D
μ_0 = Mean of Control	μ_0 = Mean of Group A
σ = Standard Deviation Groups A,B,C & D	σ = Standard deviation Groups B,C & D
n = Population size Groups A,B,C & D	n = Population size Groups B,C & D

Test #1 evaluates the hypothesis that the means of the residue data collected from buffered and non-buffered streams (Groups A, B, C and D) are equal to the mean of the control; whereas u-Test #2 tests the hypothesis that the means of the residue data obtained from the non-buffered streams (Groups B, C, and D) are equal to the mean of the residue data collected from the buffered streams (Group A). Results of these analyses are shown in Table 8 where:

- Group A = Buffered streams; Taneum River, Teanaway River and Nason Creek; Malathion
- Group B = Non-buffered streams; Gold Creek, Hansel Creek; Malathion
- Group C = Non-buffered streams, Gate Creek, Yellowjacket Creek; Sevin-4-Oil
- Group D = Non-buffered streams; Gold Creek, Hansel Creek, Gate Creek and Yellowjacket Creek; Malathion and Sevin-4-Oil.
- Control = Composite of water samples collected from the control stations and during the prespray sampling run (Run #1).

Table 8. A statistical comparison of pesticide concentrations in buffered versus non-buffered streams. 1976 Spruce Budworm Control Project in Washington State. DOE 1976.

Group	n	μ_1	σ	Test #1 $\mu_0 =$ Control	Test #2 $\mu_0 =$ Group A	u-value Test #1	u-value Test #2
A	31	3.63	5.58	0.00	--	3.62	--
B	15	9.16	14.33	0.00	3.63	2.48	1.49
C	19	2.62	3.49	0.00	3.63	3.27	- 1.26
D	34	5.51	10.23	0.00	3.63	3.14	1.07

The Test #1 u-values for Groups A, B, C and D are 3.62, 2.48, 3.27 and 3.14, respectively. All four u-values are inside the right critical regions indicating that the means of Groups A, B, C and D are not statistically equivalent to the mean of the control. Test #2 u-values of 1.49, -1.26 and 1.07 for Groups B, C and D, respectively, fall well within the 95% normal curve distribution indicating that the means of the non-buffered streams are statistically equivalent to the mean of Group A, the buffered streams.

Miscellaneous

Domestic water samples were collected from War Creek Campground, Black Pine Lake Campground, Poplar Flats Campground, Cascade Meadow and the Leavenworth Water Flume. Analysis showed that pesticide concentrations were below detection levels in these water samples.

Malathion and Sevin-4-oil concentrations were below detection levels in all of the fish and benthic organism samples that were analyzed.

Postspray water samples collected on Little Bridge Creek and Gold Creek show 9.8 ppm and 8.9 ppm Malathion, respectively (Table 3). These elevated Malathion levels in the postspray samples may have entered the stream from the higher ridges or from a subsequent spray application.

IMPACT STUDIES

Results of the impact studies are presented in the following order: Hansel Creek, a buffered stream, Middle Fork Teanaway River, a non-buffered stream and Gate Creek which flows through the Sevin-4-Oil spray block.

Hansel Creek

Drift insect sampling. Drift insect sampling began at 0001 on June 27. Insect counts in the 10-minute hourly drift samples were normal at four to eight insects per 100 cubic feet of flow (cff) through the drift nets until spraying began at about 0500 hours (Figure 2).

During the aerial application of Malathion, concentrations in the water samples rose to 36.5 ug/l at 0900 hours and declined to 0.5 ug/l at 1300 hours. Insect counts in the drift samples rose concurrently to 1003 insects per 100 cubic feet of flow through the drift nets by 1000 hours and dropped to 45 insects per 100 cubic feet by 1400 hours.

At 0900 hours the following day (June 28), Malathion concentrations in the water samples were below detection levels and insect counts returned to normal. Run #4 sampling on August 4 similarly showed normal insect counts and Malathion concentrations were below detection levels.

Diversity alterations. Average insect count comparisons and diversity alterations in the prespray, sprayday, and postspray drift insect samples also demonstrate pronounced insect activity resulting from the introduction of Malathion into the waters of Hansel Creek (Table 9).

The five 10-minute prespray samples that were collected hourly from 0001 to 0500 hours were averaged by Order and totaled. The average percent contribution of insects in these samples also was computed and tabulated. The same calculations were made on the seven 10-minute sprayday samples that were collected from 0600 to 1300 hours. Data from the three postspray samples that were collected between the hours of 0930 and 1130 the following day (June 28) received similar computations (Table 9):

Table 9. Average insect counts and average insect percent contribution by Order in the Hansel Creek prespray, sprayday, and postspray drift insect samples. DOE, 1976.

Ephem			Diptera		Trichop		Plecop		Coleop		Total
Ins. 100 ft ³	%		Ins. 100 ft ³	%	Ins. 100 ft ³	%	Ins. 100 ft ³	%	Ins. 100 ft ³	%	Ins./ 100 ft ³
Prespray 6/27/76 0001/0500	3.2	55	1.0	17	1.0	17	0.5	9	0.1	2	5.8
Sprayday 6/27/76 0600-1300	183.5	37	52.4	11	18.4	4	237.8	47	4.0	1	496.1
Postspray 6/28/76 0930-1130	3.6	48	2.4	32	0.7	9	0.8	10	0.1	1	7.6

Total counts climbed from 5.8 insects per 100 cubic feet of flow during prespray sampling to 496 insects per 100 cff on sprayday. On June 28, average postspray counts returned to 7.6 insects per 100 cff. The greatest increases were noted in Plecoptera which increased from 0.5 insects per 100 cff to 238 insects/100 cff on sprayday returning to 0.8 insects/100 cff in the postspray samples. Ephemeroptera also show dramatic increases from 3.2 insects per 100 cff during prespray to 184 insects per 100 cff on sprayday with a return to 3.6 insects per 100 cff in the postspray counts. Diversities show distinct alterations from predominantly Ephemeroptera in the prespray samples to Plecoptera on sprayday with a return to Ephemeroptera in the postspray counts.

Quantitative benthic sampling. Hansel Creek Station 1 benthic samples demonstrate a depression in the aquatic insect populations in prespray to postspray comparisons (Table 10). The mayflies were impacted most significantly at Station 1 with a decrease of 16 insects per 100 square inches. Total insect counts at Station 1 show a negative prespray - postspray deviation of -18.3 insects/100 in².

Counts from Station 3, about 2 miles downstream, show an increase of 1.7 total insects per 100 square inches, demonstrating a relatively stable condition (Table 18). Prespray to postspray deviations were minimal throughout the insect Orders at Station 3.

Table 10. Quantitative benthic samples, Stations 1 and 3. Hansel Creek, Insects per 100 square inches. Prespray, postspray and deviations. DOE 1976.

	Ephemeroptera			Diptera			Trichoptera			Plecoptera			Coleoptera			Total	
	No. Ins.	% tot.	Eph/100/in ²	No. Ins.	% tot.	Dip/100/in ²	No. Ins.	% tot.	Tri/100/in ²	No. Ins.	% tot.	Ple/100/in ²	No. Ins.	% tot.	Col/100/in ²	No.	Insects/100 in ²
Prespray Sta. #1	167	47	30	38	11	7	118	33	21	17	5	3	17	5	3	357	64.1
Postspray Sta. #1	76	30	30	22	9	4	150	59	27	5	2	1	3	1	1	256	45.8
Deviation	-91	-17	-16	-16	-2	-3	+32	+26	+6	-12	-3	-2	-14	-4	-2	-101	-18.3
Prespray Sta. #3	101	46	18	20	9	4	92	42	16	1	0	0	4	2	1	218	39.1
Postspray Sta. #3	130	42	17	15	5	2	155	51	21	6	2	1	0	0	0	306	40.8
Deviation	+29	-4	-1	-5	-4	-2	+63	+9	+5	+5	+2	+1	-4	-2	-1	+88	+1.7

Insect live boxes. Live box insects were acclimated in the program stream for approximately 12 hours and inspected immediately prior to spray application. Dead or weakened insects were either replaced or removed. Postspray counts were made about 24 hours after sprayday to permit full exposure to downstream stations. Data was recorded in terms of number of organisms exposed, number of dead organisms and percent dead (Table 11).

Table 11. Insect live box results; Hansel Creek. DOE 1976.

Station	Test organisms	Number exposed	Number dead	% dead
1.	Stoneflies	20	0	0
	Mayflies	20	5	25
	Caddisflies	19	0	0
2.	Stoneflies	21	0	0
	Mayflies	17	0	0
	Caddisflies	20	0	0
3.	Stoneflies	19	5	26.3
	Mayflies	20	19	95
	Caddisflies	17	2	11.8

Table 11. Insect live box results; Hansel Creek. DOE 1976.
(Continued)

Station	Test organisms	Number exposed	Number dead	% dead
4.	Stoneflies	18	0	0
	Mayflies	21	8	38
	Caddisflies	18	0	0
5.	Stoneflies	18	3	16.7
	Mayflies	21	2	9.5
	Caddisflies	18	0	0
Control	Stoneflies	17	0	0
	Mayflies	17	3	18
	Caddisflies	20	0	0

Although high insect mortalities were noted in the live boxes at several Hansel Creek stations and in the controls, these losses cannot be totally attributed to pesticide exposure. During the project, severe losses from siltation were noted on several occasions. Additional mortalities occurred in the live boxes due to emerging insects.

Fish live boxes. No mortalities occurred among the test organisms in the Hansel Creek fish live boxes.

Stream surveys. Stream surveys demonstrated that there were no dead or stressing fish or other animal life within or downstream of the study area during or after the spray application. Spray cards indicated that Hansel Creek received a particularly heavy spray application at Station 1.

Middle Fork Teanaway River

The information shown here was collected during the second of two Malathion applications on the Middle Fork Teanaway River.

Drift insect sampling. Drift insect sampling began at 0300 hours on July 7, 1976. Initial counts were 47 insects per 100 cubic feet of flow through the drift nets (cff) which declined to less than 10 insects per 100 cff by daylight. Aerial application of Malathion commenced at about 0600. Between 0700 and 0800 hours Malathion concentrations in the water samples reached 21 ug/l while drift insect counts increased to 77 insects/100 cff. At 0900, drift insect counts rose to 604 insects and peaked by 1000 hours at 620 insects per 100 cff. Malathion concentrations at 0900 and 1000 hours were 10 ppb and 2.3 ppb, respectively (Figure 3).

Postspray samples show Malathion concentrations below detection levels and drift insects returning to prespray levels of less than 5 insects per 100 cff (Figure 3).

Diversity alterations. Average insect count comparisons and diversity alterations again demonstrate increased insect activity in the aquatic environment with the introduction of Malathion. Identical to the Hansel Creek drift insect sampling data, the prespray, sprayday and postspray 10-minute, hourly drift insect samples were averaged by Order and totaled. The average percent contribution of insects in these samples also was computed as shown in the following table (Table 12).

Table 12. Average insect counts and average insect percent contribution by Order in the M.F. Teanaway River prespray, sprayday, and postspray drift insect samples. DOE, 1976.

	Ephem		Diptera		Trichop		Plecop		Coleop		Total
	Ins. 100 ft ³	%	Ins. 100 ft ³	%	Ins. 100 ft ³	%	Ins. 100 ft ³	%	Ins. 100 ft ³	%	Ins/100 ft ³
Prespray 7/7/76 0300-0600	9.7	34.2	15.8	56.0	1.5	5.3	1.3	4.5	0	0	28.3
Sprayday 7/7/76 0700-1200	4.9	2.0	95.2	32.0	4.3	1.5	188.9	64.5	0	0	293.0
Postspray 8/3/76 1100-1300	0.7	37.0	1.0	53.0	0	0	0.1	5.0	0.1	5.0	1.9

Total prespray counts averaged 28.3 insects per 100 cff increasing to 293.0 insects per 100 cff on sprayday declining to 1.9 insects per 100 cff in the postspray samples. The most dramatic increase in counts occurred among Plecoptera with a 1.3 per 100 cff average count in the prespray samples, rising to 189 insects/cff on sprayday declining to 0.1 at postspray. Diversity changed from predominantly Diptera in the prespray samples to Plecoptera on sprayday returning to Diptera at postspray.

Quantitative benthic samples. Benthic sampling results at Stations 1 and 5 Middle Fork Teanaway River demonstrate a relatively stable condition at both stations. The +50.6 insects per 100/in² in Diptera at Station 1 was probably the result of an insect emergence. Disregarding the Diptera at Station 1, there appears to be minor deviations throughout the Orders reflecting normal trends (Table 13).

Table 13. Quantitative benthic samples. M. F. Teanaway River, Stations 1 and 5. Insects per 100 square inches. Prespray, postspray and deviation. DOE, 1976.

	Ephemeroptera			Diptera			Trichoptera			Plecoptera			Coleoptera			Total	
	No. Ins	% tot.	Eph/100/in ²	No. Ins.	% tot.	Dip/100/in ²	No. Ins.	% tot.	Tri/100/in ²	No. Ins.	% tot.	Ple/100/in ²	No. Ins.	% tot.	Col/100/in ²	No.	Insects/100 in ²
Prespray Sta. #1	140	75	40.8	10	5	2.9	24	13	7.0	11	6	3.2	1	0	.3	186	54.2
Postspray Sta. #1	166	45	50.19	177	48	53.52	18	5	5.44	5	1	1.51	5	1	1.51	371	112.17
Deviation	+26	-30	+9.39	+167	+43	+50.62	-6	-8	-1.56	-6	-5	-1.69	+4	+1	+1.21	+185	+57.97
Prespray Sta. #5	137	67	48	39	19	13.7	23	11	8	5	2	1.7	0	0	0	204	71.52
Postspray Sta. #5	190	82	53.39	13	6	3.65	17	7	4.78	2	0	.56	11	5	3.09	233	65.47
Deviation	+53	+15	+5.39	-26	-13	-10.05	-6	-4	-3.22	-3	-2	-1.14	+11	+5	+3.09	+29	-6.05

Insect live boxes. No mortalities occurred at any of the live boxes located at Stations 1 through 5. The control station shows a loss of 7% Ephemeroptera and 5% Plecoptera which was attributed to the emergence of two insects. No livebox mortalities resulted from the Malathion application.

Table 14. Insect live box results, M. F. Teanaway River; DOE, 1976.

Station	Test Organism	Number exposed	Number dead	% dead
1.	Stoneflies	20	0	0
	Mayflies	20	0	0
	Caddisflies	20	0	0
2.	Stoneflies	20	0	0
	Mayflies	20	0	0
	Caddisflies	20	0	0
3.	Stoneflies	20	0	0
	Mayflies	20	0	0
4.	Stoneflies	20	0	0
	Mayflies	20	0	0
	Caddisflies	20	0	0
5.	Stoneflies	20	0	0
	Mayflies	20	0	0
	Caddisflies	20	0	0
Control	Stoneflies	20	1	5
	Mayflies	15	1	7
	Caddisflies	20	0	0

Fish live boxes. No mortalities occurred among the test organisms in the fish live boxes in M.F. Teanaway River.

Stream surveys. There were no dead or stressing fish or other animal life noted within or downstream of the study area during or after the spray application.

Gate Creek

Drift insect sampling. Gate Creek was one of two streams monitored in the Goat Peak area which was sprayed with Sevin-4-oil. Drift insect sampling began at 0015 hours on July 15. Insect counts remained below 20 insects/100 cubic feet of flow through the drift nets and Sevin-4-Oil concentrations in the water samples remained below detection levels till 0500 hours when spraying began (Figure 4). Concentrations climbed to 11 ug/l of water at 0900 hours and drift insect counts reached 2488 insects per 100 cff. At 1500 hours Sevin-4-Oil concentrations declined to below detection levels and drift insect counts dropped to 325 insects/100 cff. Drift insect sampling continued until 1600 hours when insect counts were holding at 240 insects/100 cff and Sevin-4-Oil concentrations rose from below detection levels to 5.6 ug/l of water. At 2300 hours an additional 10 minute drift sample was taken showing insect counts had declined to 40 insects per 100 cff.

Postspray samples collected at 0900 hours on July 17, 1976 demonstrated that drift insect counts had returned to normal at less than 10 insects per 100 cff. Sevin-4-oil concentrations were at approximately 1.6 ug/l in the postspray water samples.

Diversity alterations. Average insect count comparisons and diversity alterations in the prespray, sprayday, and postspray drift insect samples show high insect activity resulting from the introduction of Sevin-4-oil into the waters of Gate Creek (Table 15):

Table 15. Average insect counts and average insect percent contribution by Order in the Gate Creek prespray, sprayday, and postspray drift insect samples. DOE. 1976.

	Ephem		Diptera		Trichop		Plecop		Coleop		Total
	$\frac{\text{Ins.}}{100 \text{ ft}^3}$	%	$\frac{\text{Ins.}}{100 \text{ ft}^3}$	%	$\frac{\text{Ins.}}{100 \text{ ft}^3}$	%	$\frac{\text{Ins.}}{100 \text{ ft}^3}$	%	$\frac{\text{Ins.}}{100 \text{ ft}^3}$	%	$\frac{\text{Ins.}}{100 \text{ ft}^3}$
Prespray 7/15/76 0000-0500	4.6	58.0	3.0	37.5	0.0	0	0.3	3.5	0.1	1.0	8.0
Sprayday 7/15/76 0600-1600	660.5	75.0	42.7	4.8	12.8	1.5	164.2	18.7	0.0	0	880.2
Postspray 7/17/76 0900-1100	0.2	7.0	1.7	58.6	0.0	0	0.4	13.8	0.6	20.6	2.9

Total counts climbed from 8.0 insects/100 cff during prespray to 880 insects/100 cff on sprayday. On July 17, postspray counts declined to 3.0 insects/100 cff. The greatest increases were noted in Ephemeroptera which increased from 4.6 insects/100 cff prespray to 660 insects/100 cff on sprayday, and declined to less than 1 insect/100 cff postspray. Plecoptera also show a dramatic increase from less than 1 insect/100 cff prespray to 164 insects/100 cff sprayday declining to less than 1 insect/100 cff postspray. Ephemeroptera was the primary contributor in the prespray and sprayday samples, whereas Diptera was the primary contributor in the postspray samples (Table 15).

Quantitative benthic samples. Quantitative benthic samples collected at Stations 1 and 2, Gate Creek, show a pronounced decrease in benthic invertebrate populations between prespray and postspray sampling (Table 16).

Diptera were most severely affected at Station 1 with a decrease of 14 insects/100 in² after spray application. The total aquatic insect population deviation at Station 1 was -15.1 insects/100 in² of surface area. The greatest deviation at Station 2 occurred among Ephemeroptera (-22 insects/100 in² of surface area) with a total decrease of 31.7 insects/100 in² surface area (Table 16).

Table 16. Quantitative benthic samples. Gate Creek Stations 1 and 2. Insects per 100 square inches. Prespray, postspray and deviation, DOE, 1976.

	Ephemeroptera			Diptera			Trichoptera			Plecoptera			Coleoptera			Total	
	No. Ins	% tot.	Eph/100/in ²	No. Ins.	% tot.	Dip/100/in ²	No. Ins.	% tot.	Tri/100/in ²	No. Ins.	% tot.	Ple/100/in ²	No. Ins.	% tot.	Col/100/in ²	No.	Insects/100 in ²
Prespray Sta. #1	50	30	11	95	51	21	22	13	5	0	0	0	0	0	0	167	36.0
Postspray Sta. #1	27	38	8	24	34	7	17	24	5	3	4	1	0	0	0	71	20.9
Deviation	-23	+8	-3	-71	-17	-14	-5	+11	0	+3	+4	+1	0	0	0	-96	-15.1
Prespray Sta. #2	115	61	28	44	23	11	26	14	7	3	2	1	0	0	0	188	46.5
Postspray Sta. #2	25	40	6	3	5	1	19	30	5	15	24	4	1	2	1	63	14.8
Deviation	-90	-21	-22	-41	-18	-10	-7	+16	-2	+12	+22	+3	+1	+2	+1	-125	-31.7

Insect live boxes. No insect mortalities occurred in the Gate Creek live boxes. Two mayflies expired in the control station live box when they emerged. No live box insect losses resulted from the application of Sevin-4-Oil (Table 17).

Table 17. Insect live box results, Gate Creek; DOE 1976.

Station	Test organisms	Number exposed	Number dead	% dead
1.	Stoneflies	20	0	0
	Mayflies	20	0	0
	Caddisflies	20	0	0
2.	Stoneflies	20	0	0
	Mayflies	20	0	0
	Caddisflies	20	0	0
3.	Stoneflies	10	0	0
	Mayflies	10	0	0
	Caddisflies	10	0	0
Control	Stoneflies	20	0	0
	Mayflies	20	2	10
	Caddisflies	20	0	0

Fish live boxes. Four fish (20 percent) of the test organisms in the Station #2 live box died as a result of exposure to the Sevin-4-Oil spray application and the remaining 16 fish appeared to be under severe stress. No mortalities occurred in the Stations 1A and 1B live boxes, however Station #1A and 1B were at the upstream boundary of the spray block limiting live box exposure to the pesticide. Station #2 was at the extreme downstream boundary of the comparatively large spray block.

Stream surveys. No dead or stressing fish or other animal life were noted within or downstream of the study area during or after the spray application. During the postspray sample it was noted that rocks protruding from the water surface were surrounded by dead Plecoptera larvae in their early instars.

DISCUSSION

Monitoring of the 1976 Spruce Budworm Control Project went according to plan. Two streams were biologically and chemically sampled in each spray unit. The pesticide residue samples were processed by the Wenatchee Pesticide Laboratory while DOE processed the biological samples and analyzed the resulting data.

Every effort was expended to show the persistence of the pesticides in the aquatic environment, the extent of the stream reach impacted by the aerial spray project, the severity of the impacts, the aquatic organisms most severely impacted and the efficiency of buffering. Unfortunately, all of the study could not be conducted on each program stream. Yellow-jacket and Gate Creeks, the only two watercourses that flow through the Sevin-4-oil spray blocks were of insufficient length and flow to conduct the entire study and certain program modifications were required on two of the Malathion streams because of stream characteristics.

PESTICIDE RESIDUES

Water sampling. Water sampling residue data from the index streams show that pesticide concentrations were below detection levels in the prespray samples. Concentrations increased significantly in the sprayday samples and returned to approximately prespray levels in the postspray samples. The u-Test indicated that the Run #3 mean was equal to the control mean suggesting that Malathion concentrations declined to prespray levels in the aquatic environment within about 48 hours (Table 7).

Sevin-4-Oil data followed the same general trends as the Malathion information, however the u-Test showed that the Runs #2 and #3 means were not equal to the control mean (Table 7). Also the Sevin-4-Oil Run #2 mean concentrations reached only half the Malathion Run #2 levels. These deviations probably resulted from the differences in stream characteristics. Gate and Yellowjacket Creeks were short, low flow with a heavy canopy as compared to most Malathion study streams limiting the amount of spray reaching the water and retarding flushing.

Buffering. The u-Test results indicate that stream buffering during the 1976 Spruce Budworm Project had little, if any, beneficial effects (Table 8). The values derived from u-Test #1 were inside the right critical region demonstrating that the means of the pesticide concentrations in the water samples from both the buffered and the non-buffered streams were significantly higher than the normal curve distribution of the control. The u-values derived from u-Test #2 were within the normal curve distribution indicating that the means of the concentrations from the non-buffered streams were equal to those of the buffered streams.

These figures would be reversed if buffering was really effective. The means of the concentrations of the Test #1 buffered streams (Group A) would be approximately equal to those of the control, while the u-Test #2 u-values for Groups B, C and D would be inside the right critical region indicating that the means of the pesticide concentrations in the non-buffered streams are significantly higher than those in the buffered streams (Table 8).

The reasons for this reversal are not clear. It may be stream characteristics, droplet size or insufficient buffer strip width. There is, however, the possibility that buffering streams during the aerial application of pesticides to forested lands in mountain areas is not worth the effort.

IMPACT STUDIES

Drift Insect Sampling

Drift insect sampling data clearly demonstrate a pronounced increase in insect activity in the aquatic environment when pesticide concentrations of Malathion or Sevin-4-Oil reach approximately 10 ug/l in the water samples. Pesticide concentrations significantly higher than 10 ug/l caused radical increases in the drift insect counts and a high percent of the captured insects were dead (Figures 2, 3 and 4). These data clearly demonstrate the sensitivity displayed by the aquatic insects toward Malathion and Sevin-4-Oil during the 1976 Spruce Budworm Control Project.

Diversity Alterations

Alterations in insect diversity and pronounced increases in average insect counts in the drift insect samples on sprayday also demonstrate the increased activity among the aquatic insects when the pesticides were introduced into the program streams. Total average counts increased as much as 110 fold over prespray average counts returning to prespray levels at postspray sampling some 48 hours after the pesticide application. Although alterations in diversity was not consistent, Plecoptera

and Ephemeroptera seemed to be the most seriously affected of the aquatic insects (Tables 9, 12 and 15).

Quantitative Benthic Samples

Middle Fork Teanaway River benthic sampling data is not consistent with Hansel Creek and Gate Creek information, these inconsistencies probably stem from a difference in stream characteristics. The Teanaway is a larger stream of greater flow and the distance between Stations 1 and 5 was approximately five miles. Hansel and Gate Creeks are small streams of 5 to 10 cfs and only 2 miles in length. Also Gate and Hansel Creeks are slow moving over the major portion of their length permitting longer exposure to the pesticide, whereas the Teanaway is a relatively fast flowing stream.

The Middle Fork Teanaway benthic data indicates that relatively stable conditions prevailed at Stations 1 and 5 before and after sprayday (Table 13). Comparisons of prespray and postspray Hansel Creek quantitative benthic samples demonstrate a depression in the insect population after sprayday at Station #1 and a relatively stable condition at Station #3, about two miles downstream (Table 10). The data also shows that Ephemeroptera, Diptera and Plecoptera were the most seriously affected of the Orders represented and that the impacted zone extended less than two miles downstream from the spray block. Postspray samples at Station #1 show that representatives of all the insect Orders still remain indicating that recovery would be complete (Table 10).

Gate Creek benthic data show a significant postspray decline in insect counts at Station 1 and a 2-fold greater decline at Station 2, two miles downstream. However, due to stream characteristics, Station 1 was at the upstream spray block boundary and Station 2 was a short distance outside the downstream spray boundary. Postspray samples at Stations 1 and 2 show that representatives of all insect Orders remain indicating that recovery will be complete.

Insect live boxes. No mortalities occurred in the insect live boxes that could be related to the spray project. The test organisms used in the live boxes were the maturing niads destined to emerge during the current year, whereas the wild larvae that expired from exposure to the pesticide were usually very small organisms in their early instars. Insects in live boxes appear to be an excellent method of assessing impacts of water quality alterations, however they are problematic to handle, extremely sensitive to manipulations and sometimes difficult and time-consuming to obtain.

Fish live boxes. A 20 percent loss of test fish was experienced at the Gate Creek Station 2 live box and the remaining test fish in that live box were under severe stress. No other losses were observed in any of the other program stream fish live boxes or in the wild.

CONCLUSIONS

From the data gathered during the 1976 Spruce Budworm Control Project Monitoring Study, it was concluded that there was a pronounced increase in aquatic insect activity resulting from the introduction of Malathion and Sevin-4-Oil into the aquatic environment. The impacts appeared to be relatively greater on the small streams as compared to those of greater flow and Sevin-4-Oil imposed greater stress on the aquatic biota than Malathion.

However, the damage to the watercourses involved was considered minimal. Judging from insect live box studies and the Hansel Creek benthic samples, the impacts were primarily confined to the application area and about two miles downstream. Sufficient representation of all insect Orders remained in the streams to provide full recovery within a reasonable period of time. No fish mortalities were noted in the wild, however fish mortalities did occur in the Gate Creek live boxes where Sevin-4-Oil was applied. The Gate Creek spray block was large causing continuous exposure of the fish to the pesticide for an extended period.

The statistical analysis of pesticide concentrations in buffered streams versus non-buffered streams demonstrates a need for a close examination of the practicality of buffering in the mountainous regions of Washington State. Because of the dangerous flying conditions, the terrain, the height of the trees and the altitude above the ground that the helicopters must fly, buffering appears to be a futile effort. In flat-land areas, buffering probably is worthwhile; but in mountainous regions over 100-foot stands of timber, a one-swath wide buffer strip will provide minimal, if any, stream protection.

RECOMMENDATIONS

It is recommended that a dedicated effort be directed at determining the benefits derived from buffering streams during aerial spray projects with a primary objective of showing a relationship between buffer strip width, linear stream miles buffered and pesticide concentrations in the water. From the limited analysis developed on this project, it appears that buffering accomplished little if anything. Also buffering criteria and technique should be studied to limit the frequency of direct spray applications in streams designated to be buffered.

ACKNOWLEDGEMENTS

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We also appreciate the efforts of Lynden Baum, Stan Comer and their staff at the Wenatchee Pesticide Laboratory for their outstanding chemistry work and for their patience in receiving our sample deliveries at all hours of the day and night.

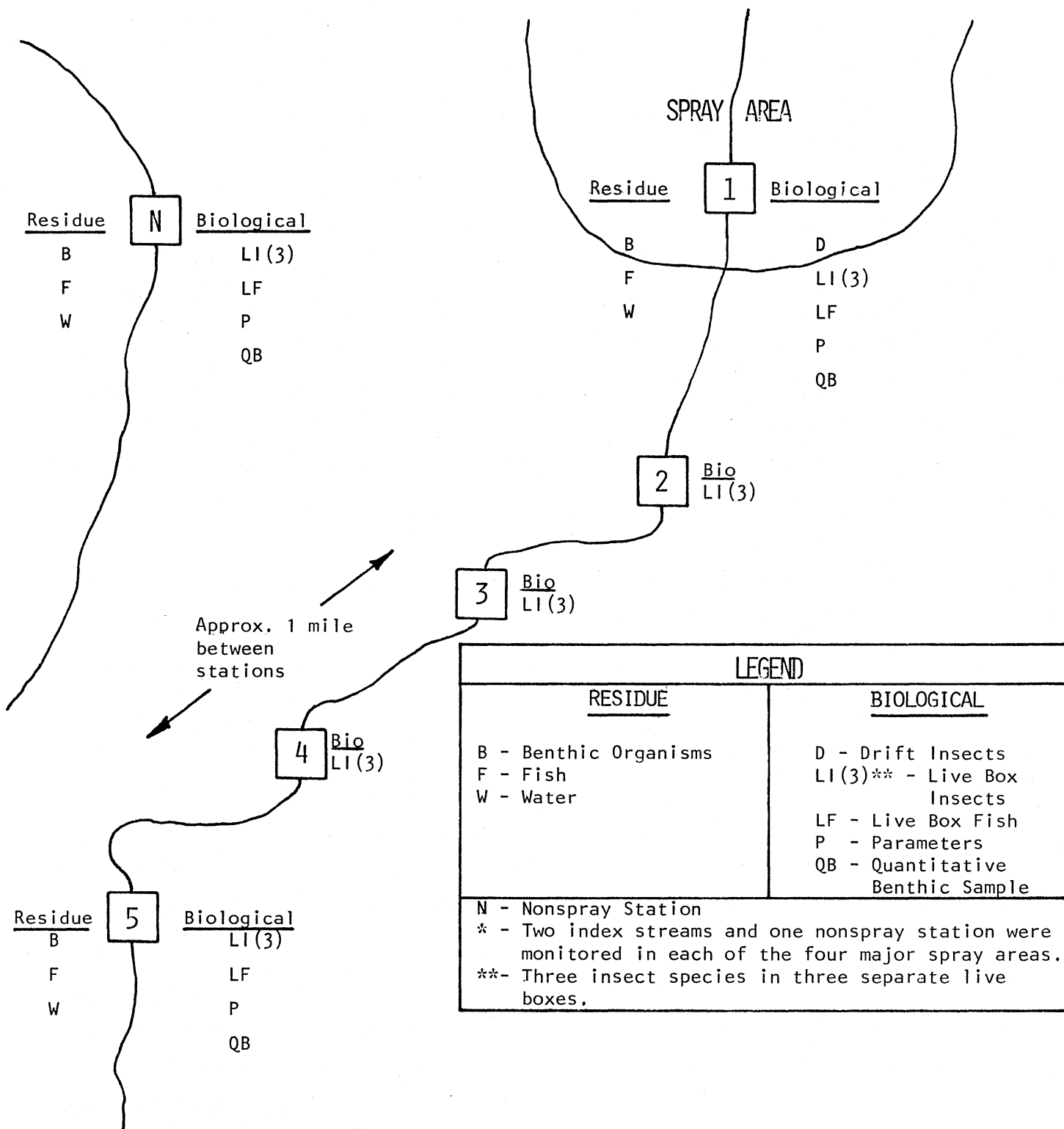
John Milhollin did the excellent graphics work and Eva Enlow typed the report. The tables were typed by Linda Talen of DOE Word Processing Center.

To these and others who participated or assisted, many thanks.

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FIGURE 1. SAMPLING STATION LAYOUT AND SAMPLE TYPES COLLECTED; ONE INDEX STREAM AND ONE NONSPRAY STATION, AQUATIC MONITORING OF THE 1976 SPRUCE BUDWORM CONTROL PROJECT, *



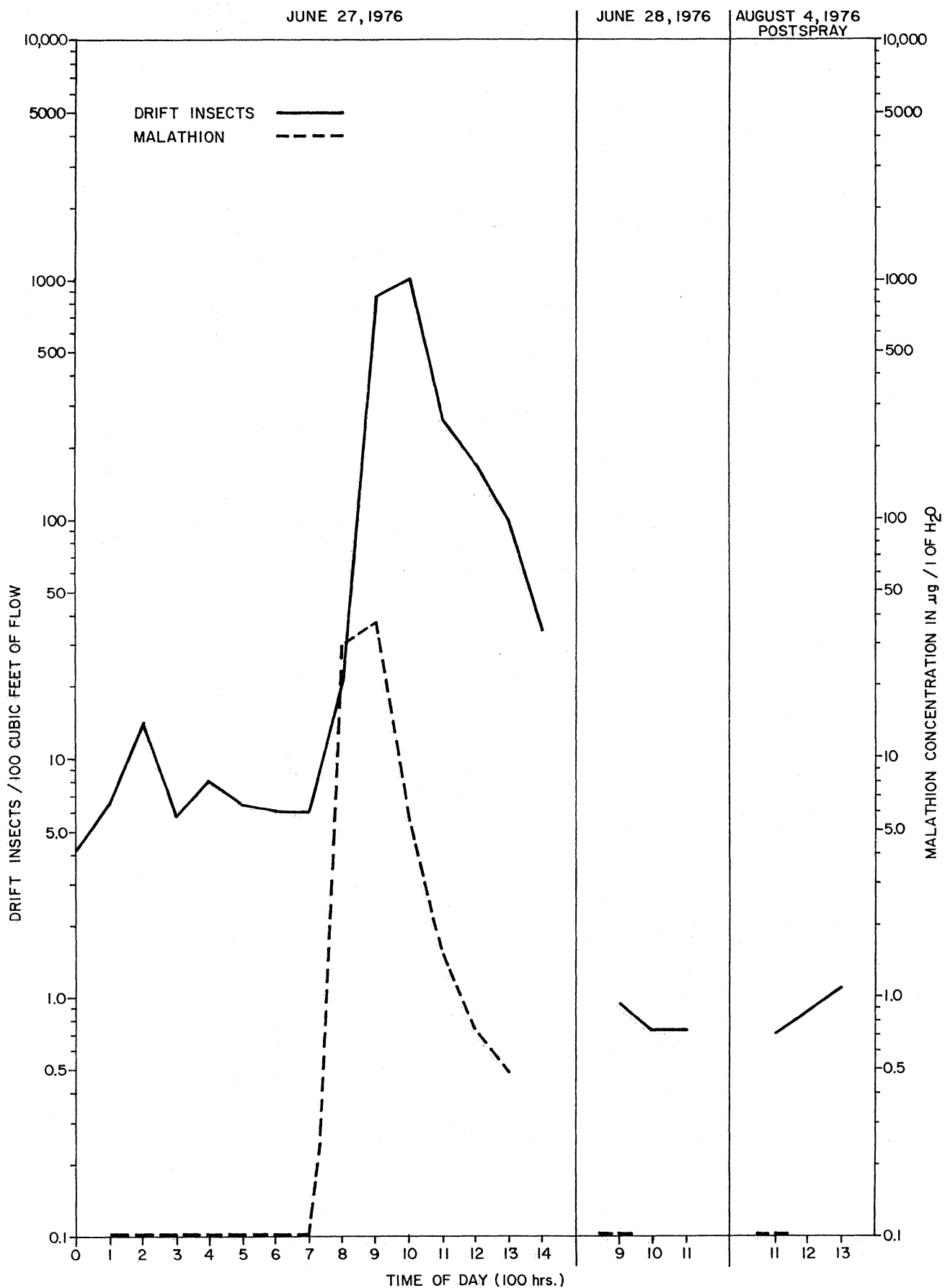


Figure 2. HANSEL CREEK. DRIFT INSECT SAMPLING, INSECTS/100 CUBIC FEET OF FLOW AND MALATHION CONCENTRATIONS IN $\mu\text{g/l}$ OF WATER.

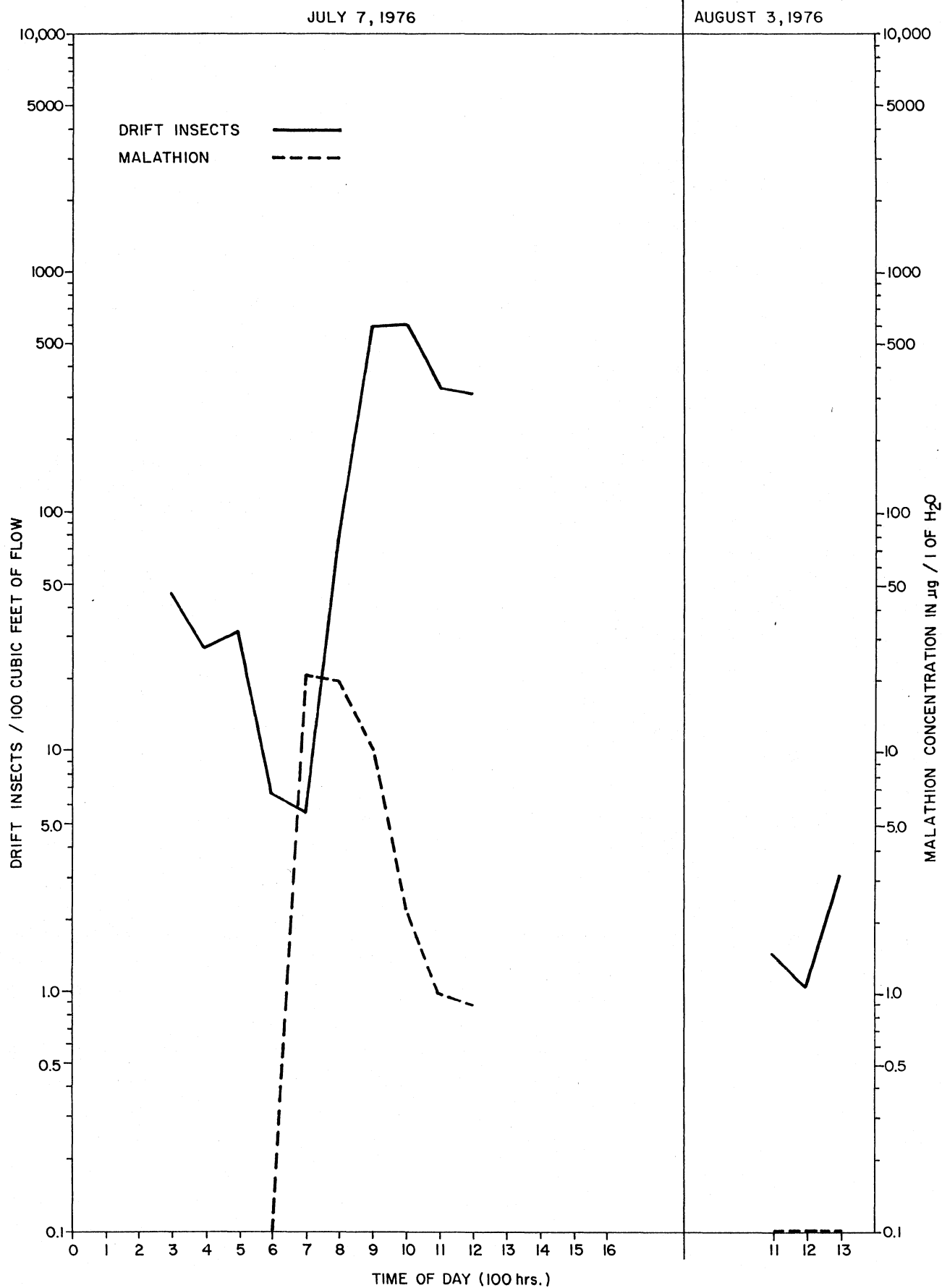


Figure 3. M.F. TEANAWAY RIVER. DRIFT INSECT SAMPLING, INSECTS / 100 CUBIC FEET OF FLOW AND MALATHION CONCENTRATIONS IN $\mu\text{g} / \text{l}$ OF WATER.

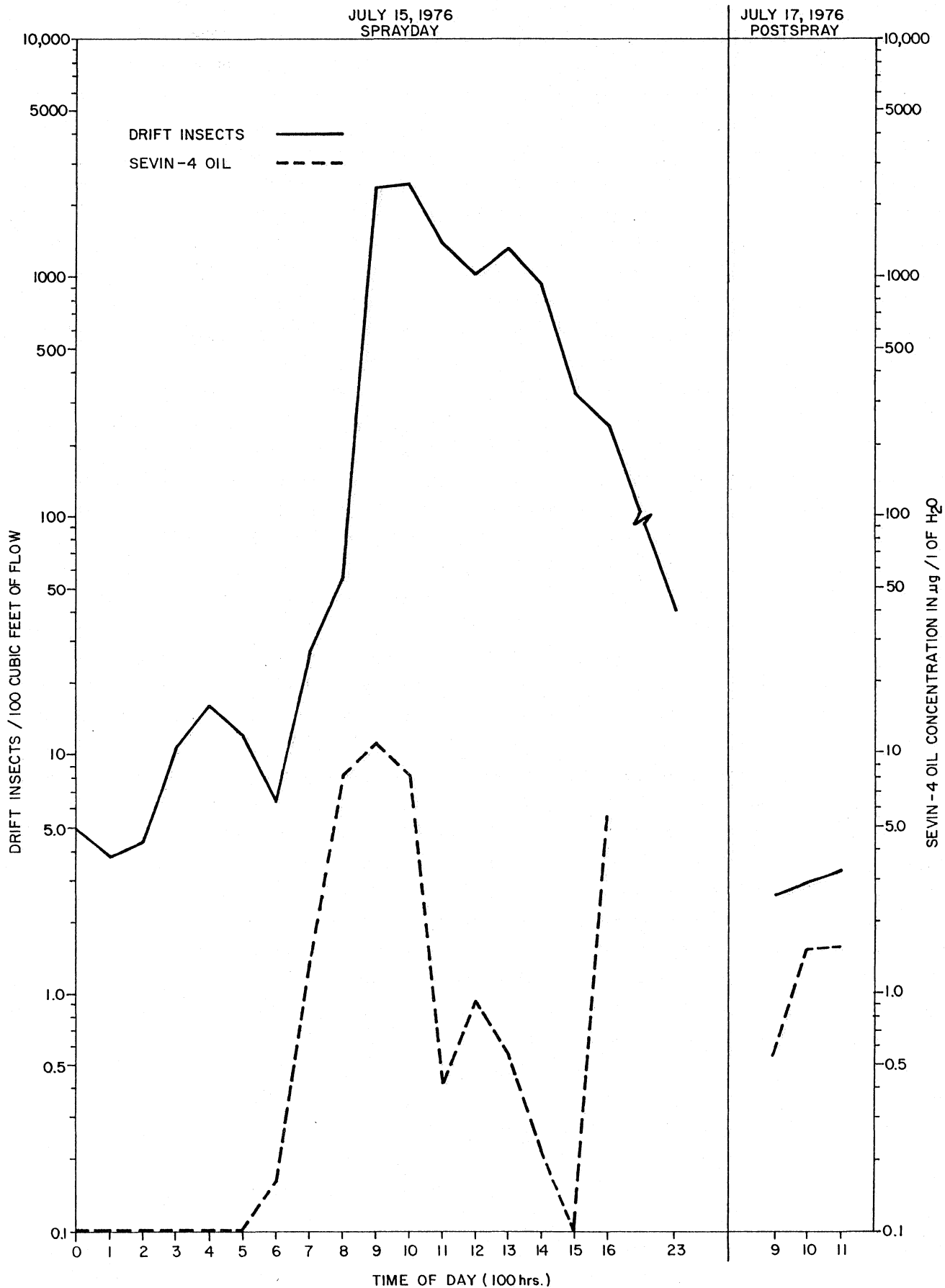


Figure 4. GATE CREEK. DRIFT INSECT SAMPLING, INSECTS / 100 CUBIC FEET OF FLOW AND SEVIN-4 OIL CONCENTRATIONS IN $\mu\text{g} / \text{l}$ OF WATER.

Table 1. Index and Control Streams; locations, pesticide type and application dates in the monitoring schedule for the 1976 Spruce Budworm Control Spray Project; Department of Ecology, 1976.

Spray Unit	Streams	Location, Station 1	Buffered	Application Dates
#1 Okanogan (Malathion)	Little Bridge Creek	T34N, R20E, Sec. 28	Yes	7/9
	Gold Creek	T32N, R21E, Sec. 30	No	7/4
	Beaver Creek (Control)	---	---	---
#2 Wenatchee (Malathion)	Hansel Creek	T23N, R17E, Sec. 21	No	6/27
	Nason Creek	T26N, R14E, Sec. 01	Yes	7/2
	Eagle Creek (Control)	---	---	---
	Hatchery Creek (Control)	---	---	---
#1 Ellensburg (Malathion)	Taneum Creek	T19N, R15E, Sec. 29	Yes	7/2
		T19N, R15E, Sec. 24	Yes	7/3
		T19N, R15E, Sec. 25	Yes	7/16
	Teanaway River (M.F.)	T21N, R15E, Sec. 21	Yes	7/5
		T21N, R15E, Sec. 15	Yes	7/7
	Little Creek (Control)	---	---	---
Goat Peak (Sevin-4-Oil)	Yellow Jacket Creek	T37N, R19E, Sec. 33	No	7/11
	Gate Creek	T36N, R19E, Sec. 15	No	7/15
	Rattlesnake Creek (Control)	---	---	---

Table 2. Sampling Schedule; 1976 Spruce Budworm Control Project Monitoring Study.

Control	Station #1	Station #2	Station #3	Station #4	Station #5
---	---	<u>PRESPRAY MISCELLANEOUS SAMPLES</u>		---	---
---	---	---	Chem	---	---
---	---	---	Para	---	---
---	---	---	Dye	---	---
---	---	---	Cfs	---	---
Live Fish	Live Fish	<u>PRESPRAY BIOLOGICAL SAMPLES</u>		---	Live Fish
Live Insects	Live Insects	---	---	---	Live Insects
---	Stone Spls.	---	---	---	Stone Spls.
Surveys	Surveys	Surveys	Surveys	Surveys	Surveys
---	Insects	<u>PRESPRAY RESIDUE SAMPLES</u>		---	Insects
---	Fish	---	---	---	Fish
---	Water	---	---	---	---
---	Drift Insects	<u>SPRAYDAY BIOLOGICAL SAMPLES</u>		---	---
Live Fish	Live Fish	---	---	---	Live Fish
Live Insects	Live Insects	---	---	---	Live Insects
---	Surveys	Surveys	Surveys	Surveys	Surveys
---	1/2 hr. water	<u>SPRAYDAY RESIDUE SAMPLES</u>		---	---
--	Spray Cards	---	---	---	---
Live Fish	Live Fish	<u>POSTSPRAY BIOLOGICAL SAMPLES</u>		---	Live Fish
Live Insects	Live Insects	---	---	---	Live Insects
---	Stone Spls.	---	---	---	Stone Spls.
Surveys	Surveys	Surveys	Surveys	Surveys	Surveys
---	Insects	<u>POSTSPRAY RESIDUE SAMPLES</u>		---	Insects
---	Fish	---	---	---	Fish
---	Water	---	---	---	---
---	Spray Cards	---	---	---	---

TABLE 3. RESIDUE SAMPLE ANALYSES - 1976 SPRUCE BUDWORM CONTROL PROJECT - DOE 1976

STREAM	Station	Run	DATE	MALATHION CONCENTRATIONS ¹																								
				Water - µg/l												Benthic Organisms µg/g						Fish - ' µg/g						
Little	1	1	7/9	K	K	K	K	K	K	K	K	K	K	K	K									K				
Bridge Cr.		3	7/13 & 8/5	9.8	K											K								K				
	4	1	7/9													K								K				
		3	7/13													K								K				
Gold Creek	1	1	7/4	K	K	K	K	K								K								NA				
		2	7/4	2.4	42.	4.3	4.2	2.9	1.4	1.3																		
		3	7/6 & 8/5	.26	8.9											K								NA				
	5	1	7/2													K								NA				
		3	7/6	.41												K								NA				
War Creek		2	7/5	K																								
(campground rinse water)		3	7/13	K																								
Black Pine		2	7/6	K	K																							
Lake (camp- ground - tap water)		3	7/13	K																								
Poplar Flats		2	7/6	K	K																							
(campground - tap water)		3	7/13	K																								

¹ K represents concentrations of Malathion below the lower detectable limits of the analysis.
 NA identifies samples not analysed by the Wenatchee Pesticide Laboratory.

TABLE 4. RESIDUE SAMPLE ANALYSES - 1976 SPRUCE BUDWORM CONTROL PROJECT - DOE 1976

STREAM	Station	Run	DATE	MALATHION CONCENTRATIONS ¹																									
				Water - µg/l										Benthic Organisms µg/g					Fish - µg/g										
Nason Creek	1	1	6/29 - 7/2	K	K	K	K	K	K	K							K							NA	NA				
		2	7/2	1.6	.67	2.8	2.6	.78	.27																				
		3	7/2 & 8/4	K													K								NA				
	1	4	6/29														K								NA				
Hansel Creek	1	1	6/23 - 6/27	K	K	K	K	K	K	K							K								NA				
		2	6/27	.25	30.	37.	3.1	5.8	1.6	.73	.41																		
		3	6/28 & 8/4	K	K												K								NA	NA			
	3	1	6/24														K								NA				
	4	3	6/28														K								NA	NA			
Cascade Meadow (domestic water supply)		2	6/30	K																									
Leavenworth Water Flume (domestic water reservoir)		1	7/2	K																									

¹ K represents concentrations of Malathion below the lower detectable limits of the analysis.
 NA indicates samples not analysed by the Wenatchee Pesticide Laboratory.

TABLE 5. RESIDUE SAMPLE ANALYSES - 1976 SPRUCE BUDWORM CONTROL PROJECT - DOE 1976

STREAM	Station	Run	DATE	MALATHION CONCENTRATIONS ¹																							
				Water - µg/l										Benthic Organisms					Fish - µg/g								
														µg/g													
Taneum	1	1	7/2	K	K	K	K	K	K							K	K					NA	NA				
Creek*		2	7/2	1.6	17.	3.3	3.1	1.2	.53																		
(1st spray)		3	7/6 & 8/3	K	K												K						NA				
	5	1	7/2																				NA				
		3	7/6														K						NA				
(3rd spray)	1	1	7/16	K	K	K	K																				
		2	7/16	1.2	.65	4.4	4.0	2.3	2.9	2.9																	
		3	7/17	K													K						K				
	5	3	7/17	K													K						K				
Teanaway	1	1	7/5	K	K	K											K						NA				
River (M.F.)		2	7/5	1.3	1.1	.63	.56	K	K																		
(1st spray)		3	7/8 & 8/3	K	K												K						NA				
	5	1	7/5														K						NA				
		3	7/8														K						NA				
(2nd spray)	1	1	7/7	K	K	K	K																				
		2	7/7	21.	20.	10.	2.3	1.0	.88																		

¹ * Residue samples were collected during two of three spray application in the Taneum Creek area.

K represents concentrations of Malathion below the lower detectable limits of the analysis.

NA indicates samples not analysed by the Wenatchee Pesticide Laboratory.

TABLE 6. RESIDUE SAMPLE ANALYSIS - 1976 SPRUCE BUDWORM CONTROL PROJECT - DOE 1976

STREAM	Station	Run	DATE	SEVIN-4-OIL CONCENTRATIONS ¹																						
				Water - µg/l										Benthic Organisms µg/g					Fish - µg/g							
Gate Creek	1	3	7/17													K										
	2	1	7/15	K	K	K	K	K	K							K										
		2	7/15	.16	1.4	8.1	11	8.4	.43	.95	.56	.22	K	5.6	.55							NA				
		3	7/17	1.5	1.6											K						NA				
Yellow	1	3	7/11																			NA				
Jacket Cr.	2	1	7/11	K	K	K	K	K	K							K										
		2	7/11	5.0	1.3	1.0	.28	K	K	K																
		3	7/11 & 7/13	K												K										

¹ K represents concentrations of Sevin-4-Oil below the lower detectable limits of the analysis.
 NA indicates samples not analysed by the Wenatchee Pesticide Laboratory.